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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

# WARTIME REPORT

ORIGINALLY ISSUED

March 1942 as  
Advance Restricted Report

PRESSURE-DROP CHARACTERISTICS OF ORIFICE PLATES

USED TO SIMULATE RADIATORS

By K. R. Czarnecki

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## NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

## ADVANCE RESTRICTED REPORT

PRESSURE-DROP CHARACTERISTICS OF ORIFICE PLATES  
USED TO SIMULATE RADIATORS

By K. R. Ozarnecki

## SUMMARY

An investigation of the pressure-drop characteristics of orifice plates has been conducted to facilitate the design of resistances to simulate various types of cooling units. It was found that the use of orifice plates is practical because of the simple construction of the plates, the ease with which the pressure drop can be varied by the use of corks, and the absence of any large scale effects. The orifice coefficient was found to vary as the 0.041 power of the pressure-drop coefficient times the constant 0.69.

## INTRODUCTION

In tests of cooling-air ducts it is inconvenient and often impractical to use model radiators, particularly when the model being tested is only a fraction of the size of the original airplane. For wind-tunnel tests, resistances, such as screens and orifice plates, are generally used to simulate the radiators. In order to facilitate such tests, an investigation of the pressure-drop characteristics of orifice plates has been conducted.

Wind-tunnel tests have shown that the pressure-drop coefficient of a screen or combination of screens is dependent upon the velocity of the air through it (fig. 1), and considerable calibration is required before the actual testing can begin. The tests of the orifice plates were made to determine the practicability of using such plates to simulate radiators and to obtain data from which the plates could be designed. Some modifications in the arrangement of the orifices and in the method of mounting the orifice plate in the duct were also investigated over a range of Reynolds numbers. These tests were made by the NACA at the Langley Memorial Aeronautical Laboratory, Langley Field, Va.

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## SYMBOLS

$\Delta p$  pressure drop across orifice plate  
 $C$  orifice coefficient  
 $q_R$  dynamic pressure at face of orifice plate

$\Delta p/q_R$  pressure-drop coefficient

$t$  thickness of orifice plate

$A_H$  open-hole area

$A_{H_e}$  effective open-hole area

$A_R$  orifice-plate area

$D$  diameter of holes

$V_H$  velocity through hole

$\nu$  kinematic viscosity

$R$  Reynolds number ( $V_H D / \nu$ )

## EQUIPMENT AND METHODS

Four aluminum orifice plates, 1/4 inch thick, were tested. Three of the plates were rectangular (fig. 2) and of identical construction; the fourth was semicircular and had a different hole spacing (fig. 3). The holes were 3/4 inch in diameter and were punched in the same direction in each plate. Excessively large burrs left by the punching process were removed, but no attempt was made to file the edges of the holes smooth.

The orifice plates were installed in ducts of uniform cross section (figs. 4 and 5) and were mounted in the open test section of the 1/15-scale model of the NACA full-scale wind tunnel (reference 1). In general, the plates were installed with the rough faces on the downstream side and with the spaces between the plates and the duct walls

unsealed. Several runs were made, however, to determine the effect of installing the plate with the rough face forward and of sealing the gap between the plates and the duct walls. Grids of 1/16-inch diameter total- and static-pressure tubes were installed both at the front faces of the plates and at some station downstream of the plates. In the rectangular duct the rear grid of tubes was located at three different distances (15, 26, and 45 inches) behind the resistance in order to determine the effects of the turbulence on the results; in the second duct the grid was located 36 inches behind the resistance. In some of the tests at low airspeeds, in order to improve the accuracy of the velocity measurements, a constriction was built into the rear of the duct and the velocity measurements were made at that station.

Corks, 3/4 inch in diameter at the middle section, were inserted in the orifice plates from front to rear to obtain various pressure drops. Various patterns giving the same ratios of open area to plate area were investigated. The effect of varying the cork size and of inserting the corks from rear to front was also determined. Ratios of free area to plate area from 0.038 to 0.580 were investigated over a range of Reynolds numbers from 5,000 to 50,000.

## RESULTS AND DISCUSSION

Typical curves of the nondimensional pressure-drop coefficient  $\Delta p/q_R$  plotted against Reynolds number are shown in figure 6. The loss in total pressure across the plate, which was checked against the loss in static pressure, was used to compute the coefficient. No appreciable scale effects were found for any of the open-area to plate-area ratios tested. A variation of the pressure drop with the Reynolds number is usually caused by a change in location of the point of separation of the air stream from the solid boundary. The use of sharp-edge holes, such as those in the orifice plate, fixes the point of separation at the sharp front edge of the holes and minimizes scale effect.

It was found that, for a given  $A_H/A_R$  ratio, the pressure-drop coefficient for an individual orifice plate might vary approximately 3 percent from the average for

the four plates. This variation, which was probably due to the use of dies having varying degrees of sharpness, could be eliminated, at least partly, by the complete removal of burrs left by the punching process. The installation of the plate with the rough face forward or the use of rough corks increased the pressure-drop coefficient approximately 3 percent; however, sealing the gap between the plate and the duct wall, inserting the corks from rear to front, or changing the cork size caused no change in the pressure drop within the experimental accuracy of the tests. Only an extreme nonuniformity of distribution of the corks caused any noticeable effect on the pressure drop.

The average pressure-drop coefficients and corresponding orifice coefficients are presented in figure 7. The orifice coefficient is defined as

$$C = \frac{A_{He}}{A_H} \quad (1)$$

where the effective open area,  $A_{He}$ , is defined by the equation

$$\Delta p = q_R \left( \frac{A_R}{A_{He}} - 1 \right)^2 \quad (2)$$

Accordingly,

$$C = \frac{A_R/A_H}{\left( \frac{\Delta p}{q_R} \right)^{1/2} + 1} \quad (3)$$

It was found that the orifice coefficient could be represented by the equation

$$C = 0.69 \left( \frac{\Delta p}{q_R} \right)^{0.041} \quad (4)$$

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Figure 7 also shows the variation of pressure-drop coefficient with the ratio of open area to plate area for a built-up orifice plate having a thickness of 1 inch and holes of 3/4-inch diameter (reference 2). The edges of the holes were sharp as in the case of the orifice plates tested. The two sets of results are approximately in agreement.

### CONCLUDING REMARKS

1. The use of orifice plates to simulate radiators is quite practical because of the simple construction of the plates, the ease with which the pressure drop can be varied by the use of corks, and the absence of any large scale effects.

2. It was found that the orifice coefficient varied as the 0.041 power of the pressure-drop coefficient times the constant 0.69.

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### REFERENCES

1. Theodorsen, Theodore, and Silverstein, Abe: Experimental Verification of the Theory of Wind-Tunnel Boundary Interference. Rep. No. 479, NACA, 1934.
2. Nickle, F. R., and Freeman, Arthur B.: Full-Scale Wind-Tunnel Investigation of Wing Cooling Ducts. NACA A.C.R., Oct. 1938.

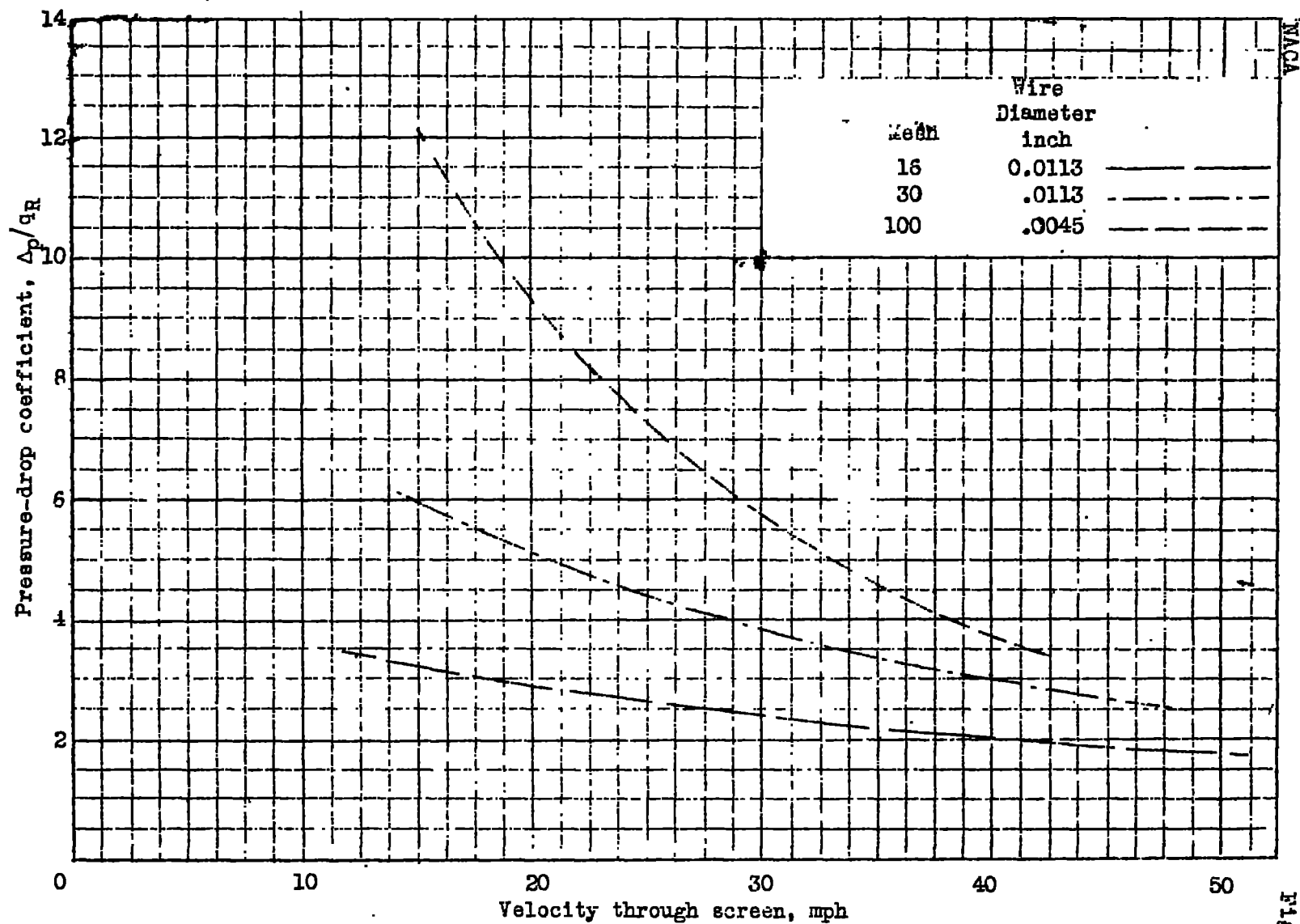


Figure 1.- Variation of pressure-drop coefficient with velocity through screen.

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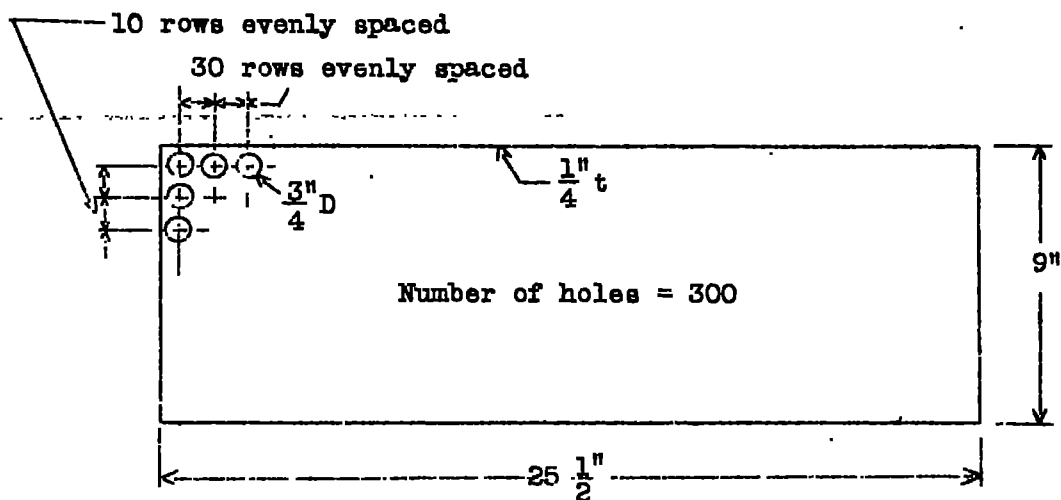


Figure 2.- Dimensions of orifice plates 1, 2, and 3.

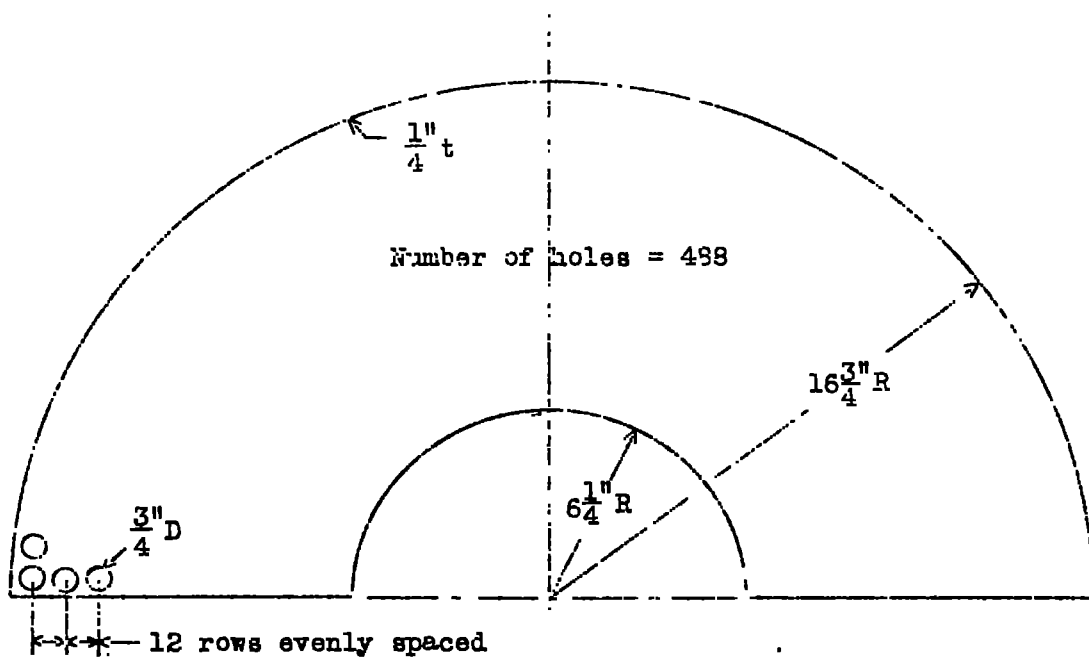


Figure 3.- Dimensions of orifice plate 4.



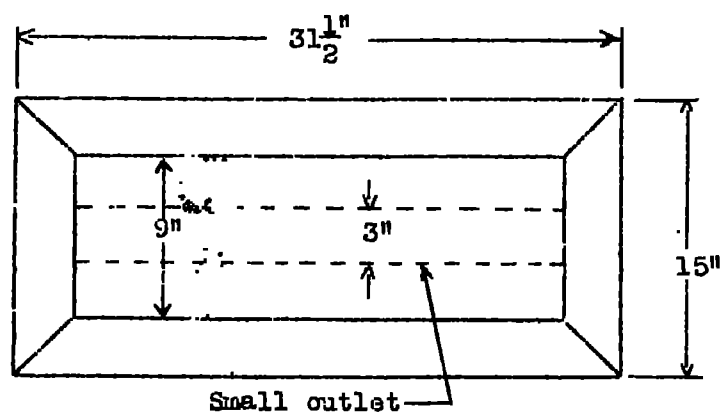
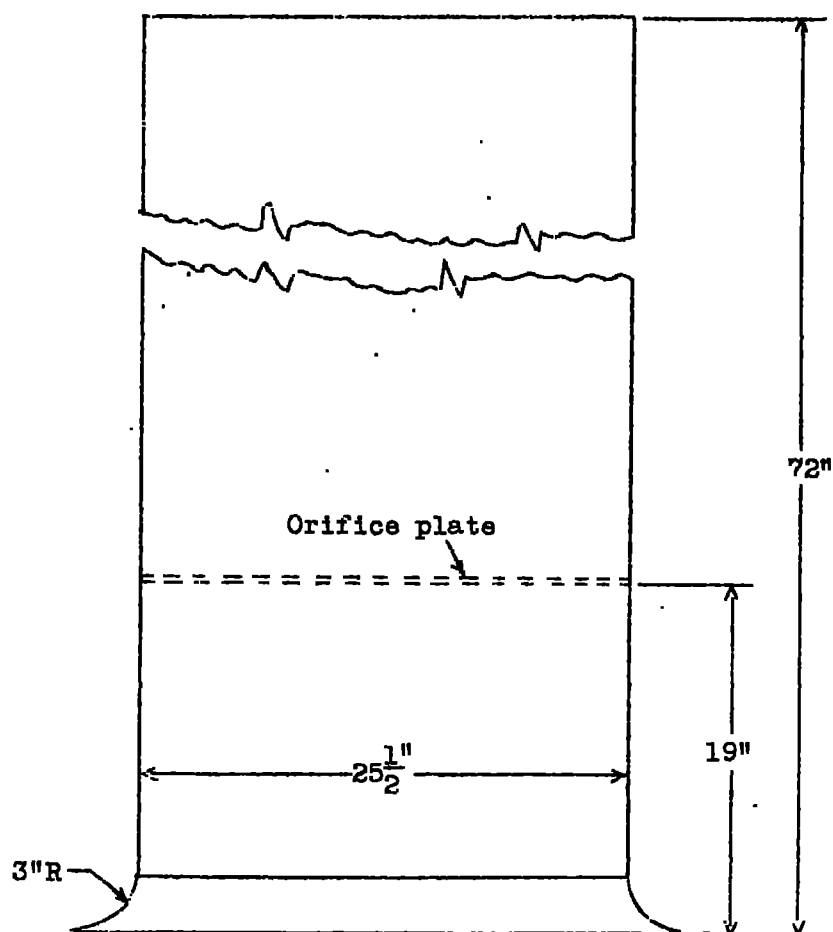


Figure 4.- Dimensions of duct used in testing orifice plates 1, 2, and 3.

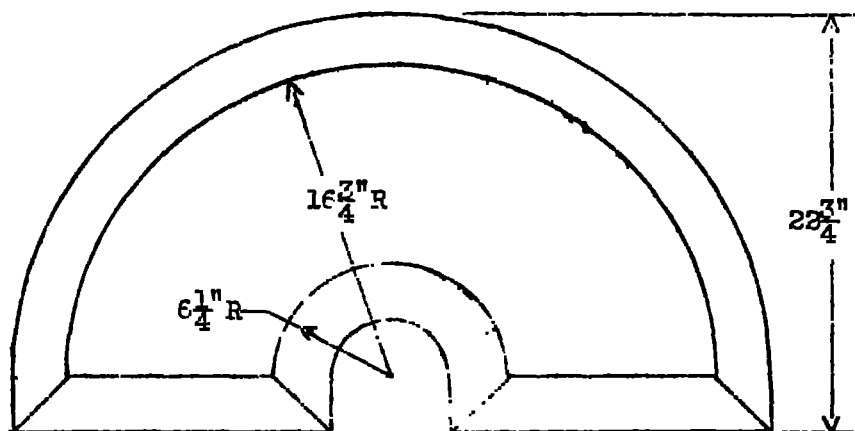
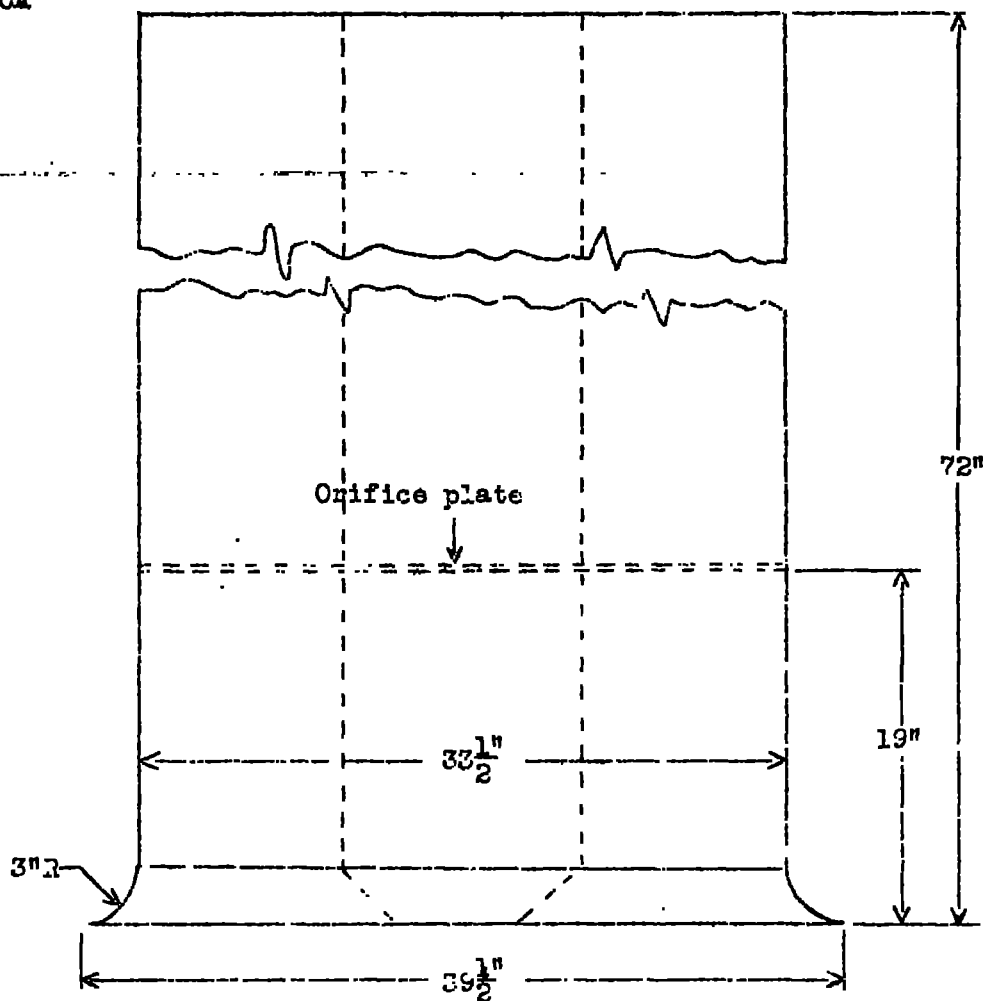


Figure 5.- Dimensions of duct used in testing orifice plate 4.

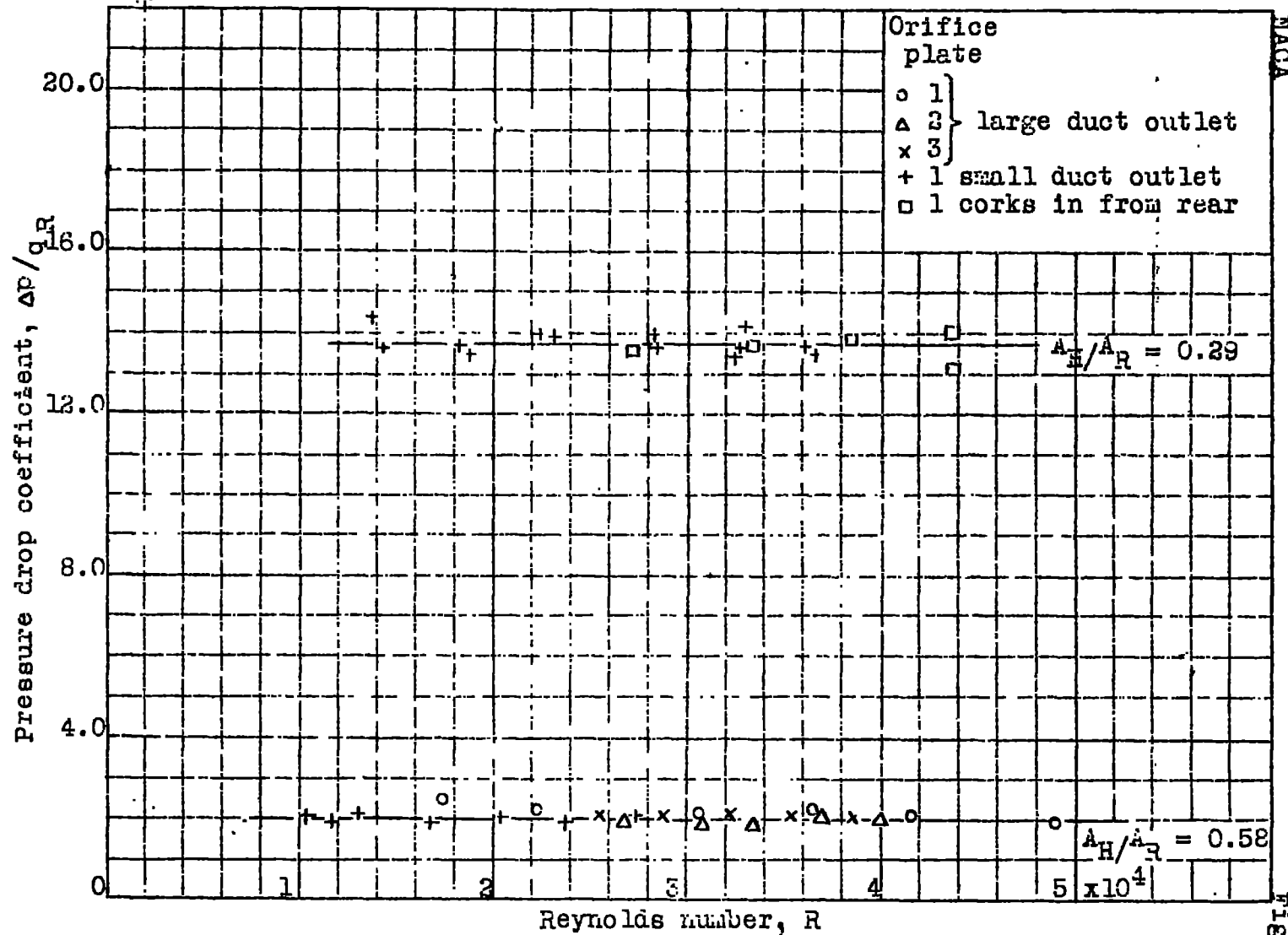


Figure 6.- Effect of Reynolds number on pressure-drop coefficient.

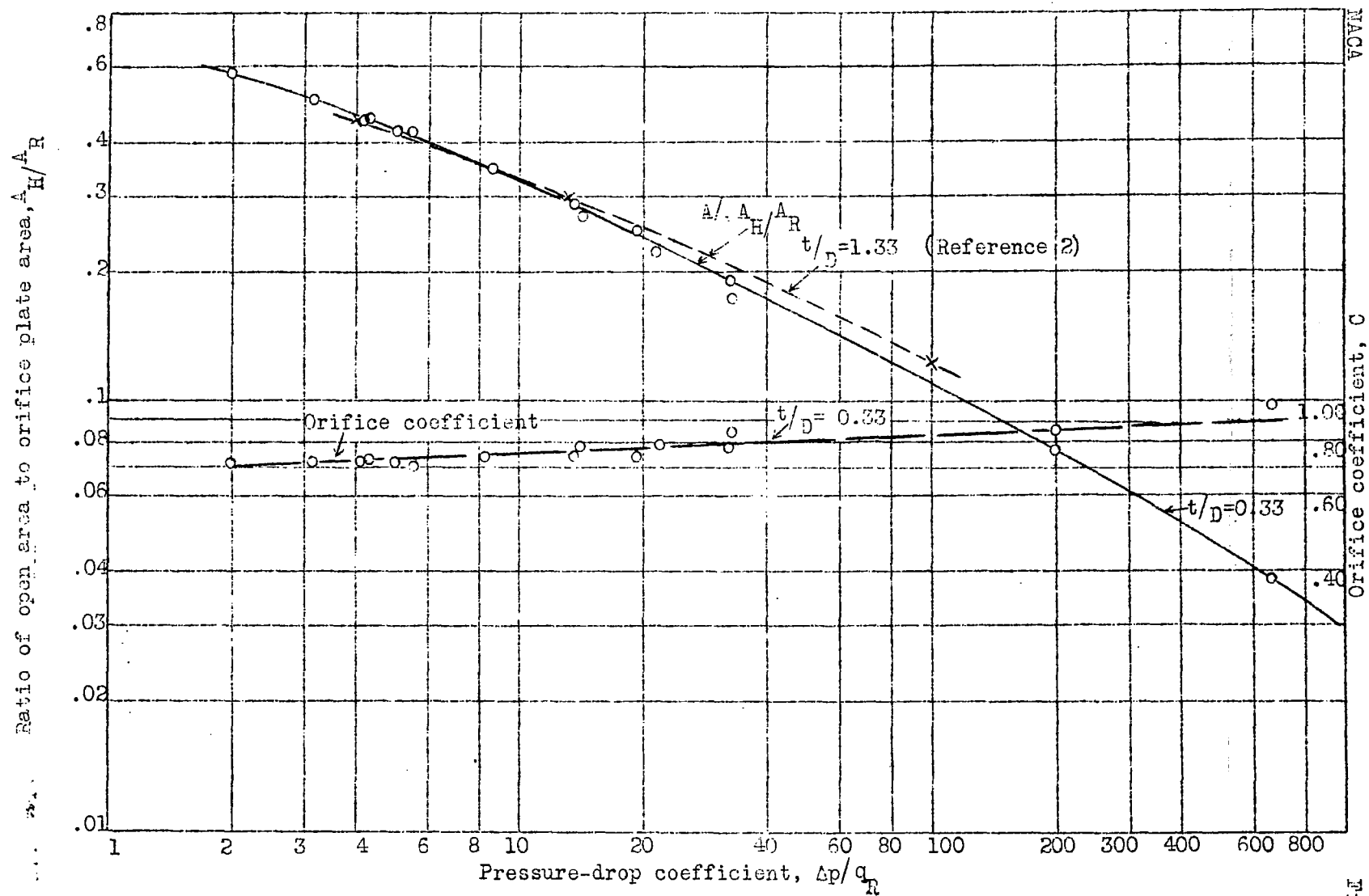


Figure 7.- Curve showing effect of ratio of open area to plate area on pressure-drop coefficient. Also curve of computed orifice coefficients.

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